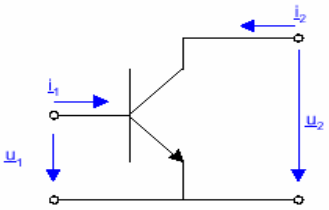
3.1.2 Grundschaltungen

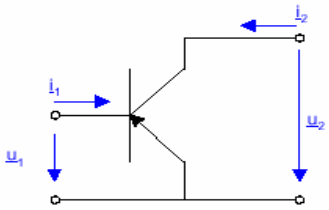
Name nach gemeinsamer Elektrode für Ein- und Ausgang.

- nur npn - Transistor (pnp ist analog)

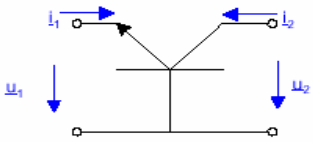
Emitterschaltung



Kollektorschaltung



Basisschaltung



Vierpolparameter sind vom Arbeitspunkt abhängig.

Umrechnung der h - Parameter

Emitterschaltung	Basisschaltung	Kollektorschaltung
h_{11e}	$h_{11b} = \frac{h_{11e}}{1 + h_{21e}}$	$h_{11C} = h_{11e}$
h_{12e}	$h_{12b} = \frac{\Delta h_e - h_{12e}}{1 + h_{21e}}$	$h_{12C} = 1 - h_{12e} \approx 1$
h_{21e}	$h_{21b} = -\frac{h_{21e}}{1 + h_{21e}}$	$h_{21C} = -(1 + h_{21e})$
h_{22e}	$h_{22b} = \frac{h_{22e}}{1 + h_{21e}}$	$h_{22C} = h_{22e}$

Umrechnung der Y-Parameter(bei hohen Frequenzen)

Emitterschaltung	Basisschaltung	Kollektorschaltung
Y_{11e}	$Y_{11b} = \sum Y_e$	$Y_{11C} = Y_{11e}$
Y_{12e}	$Y_{12b} = -(Y_{12e} + Y_{22e})$	$Y_{12C} = -(Y_{11e} + Y_{12e})$
Y_{21e}	$Y_{21b} = -(Y_{21e} + Y_{22e})$	$Y_{21C} = -(Y_{11e} + Y_{21e})$
Y_{22e}	$Y_{22b} = Y_{22e}$	$Y_{22C} = \sum Y_e$

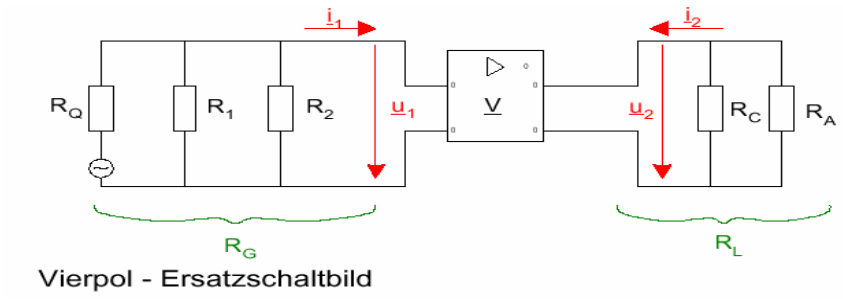
Umrechnung h - $\rightleftharpoons$ Y - Parameter

Gilt nur für den NF - Bereich!

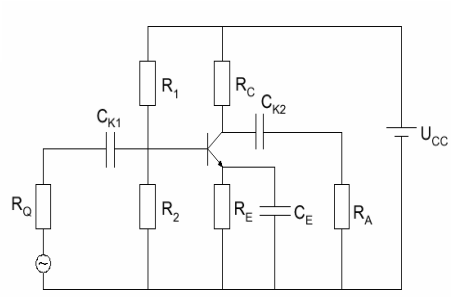
h - Werte	Y - Werte
$h_{11} = \frac{1}{Y_{11}}$	$Y_{11} = \frac{1}{h_{11}}$
$h_{12} = -\frac{Y_{12}}{Y_{11}}$	$Y_{12} = -\frac{h_{12}}{h_{11}}$
$h_{21} = \frac{Y_{21}}{Y_{11}}$	$Y_{21} = \frac{h_{21}}{h_{11}}$
$h_{22} = \frac{\Delta Y}{Y_{11}}$	$Y_{22} = \frac{\Delta h}{h_{11}}$

Betriebsgrößen des Verstärkers !!!
(dynamisches Verhalten)

1. Emmiterschaltung(ohne Gegenkopplung)



Vierpol - Ersatzschaltbild



Schaltung einer Verstärkerstufe

Eingangswiderstand

$$\underline{Z}_{ein_{Tr}} = \frac{\underline{u}_1}{\underline{i}_1} = \frac{h_{11} + \Delta h * R_L}{1 + h_{22} * R_L}$$

$$\underline{Z}_{ein_{Tr}} = \frac{1 + Y_{22} * R_L}{Y_{11} + \Delta Y * R_L}$$

$$\underline{Z}_{ein_{St}} = R_1 \,//\, R_2 \,//\, \underline{Z}_{ein_{TV}}$$

Ausgangswiderstand

$$\underline{Z}_{aus_{Tr}} = \frac{\underline{u}_2}{\underline{i}_2} = \frac{R_G + h_{11}}{\Delta h + h_{22} + R_G}$$

$$\underline{Z}_{aus_{Tr}} = \frac{1 + Y_{11} * R_G}{Y_{22} + \Delta Y * R_G}$$

$$\underline{Z}_{aus_{St}} = \underline{Z}_{aus_{Tr}} \,//\, R_C \qquad R_G = R_Q \,//\, R_1 \,//\, R_2$$

Spannungsverstärkung

$$\underline{V}_u = \frac{\underline{u}_2}{\underline{u}_1} = -\frac{h_{21} * R_L}{h_{11} + \Delta h * R_L}$$

$$\underline{V}_u = -\frac{Y_{21} * R_L}{1 + Y_{22} * R_L}$$

Stromverstärkung

$$\underline{V}_i = \frac{\underline{i}_2}{\underline{i}_1} = \frac{h_{21}}{1 + h_{22} * R_L}$$

$$\underline{V}_i = \frac{Y_{21}}{Y_{11} + \Delta Y * R_L}$$

$$\underline{V}_{i_{St}} = \frac{R_E}{R_E + \underline{Z}_{ein_{Tr}}} * \underline{V}_{i_{Tr}} * \frac{R_C}{R_C + R_A}$$

Näherungen für die Emmiterschaltung

$h_{12_e} \Rightarrow 0$ (praktisch < 10^{-3})

$\rightarrow \Delta h_e \approx h_{11_e} * h_{22_e}$ (0,110)

$$\underline{Z}_{ein_{Tr}} = \frac{h_{11_e} + \Delta h_e * R_L}{1 + h_{22_e} * R_L}$$

$h_{22_e} * R_L \ll 1$

$$\underline{Z}_{ein_{Tr}} = \frac{h_{11_e} + \left(h_{11_e} * h_{22_e}\right) * R_L}{1 + h_{22_e} * R_L} = \frac{h_{11_e} * \left(1 + h_{22_e} * R_L\right)}{\left(1 + h_{22_e} * R_L\right)}$$

$$\underline{Z}_{ein_{Tr}} \approx h_{11_e}$$

$$h_{11_e} \approx \frac{u_T}{i_B} = \frac{u_T * h_{21_e}}{i_C}$$

$$\underline{Z}_{aus_{Tr}} = \frac{h_{11_e} + R_G}{\Delta h_e + h_{22_e} * R_G} \approx \frac{h_{11_e} + R_G}{h_{11_e} h_{22_e} + h_{22_e} * R_G} = \frac{\left(h_{11_e} + R_G\right)}{h_{22_e} * \left(h_{11_e} + R_G\right)}$$

$$\underline{Z}_{aus_{Tr}} \approx \frac{1}{h_{22_e}}$$

$$\underline{V}_{u_{Tr}} = -\frac{h_{21_e} * R_L}{h_{11_e} + \Delta h_e * R_L} \approx -\frac{h_{21_e} * R_L}{h_{11_e} + h_{11_e} * h_{22_e} * R_L} = -\frac{h_{21_e} * R_L}{h_{11_e}\left(1 + h_{22_e} * R_L\right)}$$

$$\underline{V}_{u_{Tr}} \approx -\frac{h_{21_e} * R_L}{h_{11_e}}$$

$$\underline{V}_{i_{Tr}} = \frac{h_{21_e}}{1 + h_{22_e} * R_L} \approx h_{21_e}$$

2. Emmiterschaltung(mit Gegenkopplung)

Nachteil der Gegenkopplung : Verstärkungsminderung

Vorteile der Gegenkopplung :

stabilisiert gegen	verringert	verändert
Spannungs-schwankungen	Verzerrungen	Frequenzgang
Exemplar-streuungen		Eingangs-widerstand
Alterung		Ausgangs-widerstand
Temperatur-einflüße		

Reihen - Reihen - Schaltung
(Serien - Serien - Schaltung)

$$\underline{i}_1' = \underline{i}_1 \quad ; \quad \underline{i}_2' = \underline{i}_2$$

$$\underline{V}_i' = \frac{\underline{i}_2'}{\underline{i}_1'} = \underline{V}_i = \frac{\underline{i}_2}{\underline{i}_1}$$

Parallel - Parallel - Schaltung

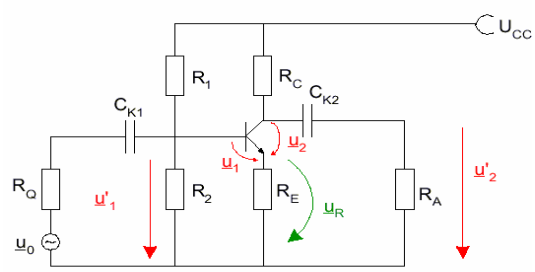
$$\underline{u}_1' = \underline{u}_1 \quad ; \quad \underline{u}_2' = \underline{u}_2$$

$$\underline{V}_u' = \frac{\underline{u}_2'}{\underline{u}_1'} = \underline{V}_u = \frac{\underline{u}_2}{\underline{u}_1}$$

$$\underline{V}_u' = \frac{\underline{V}_u}{1 - \underline{K}_u * \underline{V}_u}$$

$$\underline{k}_u = \frac{\underline{u}_K}{\underline{u}_2'}$$

Stromgegenkopplung:



Reihen - Reihen - Gegenkopplung

Für die Emitterschaltung gilt :

$$h_{21_e} >> 1 \quad ; \quad h_{12_e} << 1 \quad ; \quad h_{22_e} * R_E << 1$$

Man erhält folgende Näherungen :

$$h'_{11_e} \approx h_{11_e} + h_{21_e} * R_E$$
$$h'_{12_e} \approx h_{12_e} + h_{22_e} * R_E$$
$$h'_{21_e} \approx h_{21_e}$$
$$h'_{22_e} \approx h_{22_e}$$

$$h'_{11_e} = \frac{h_{11_e} * \left(1 + h_{22_e} * R_E\right) + R_E\left(1 - h_{12_e}\right) * \left(1 + h_{21_e}\right)}{1 + h_{22_e} * R_E}$$

$$h'_{12_e} = \frac{h_{12_e} + h_{22_e} * R_E}{1 + h_{22_e} * R_E}$$

$$h'_{21_e} = \frac{h_{21_e} - h_{22_e} * R_E}{1 + h_{22_e} * R_E}$$

$$h'_{22_e} = \frac{h_{22_e}}{1 + h_{22_e} * R_E}$$

$$\Delta h_e' = h'_{11_e} * h'_{22_e} - h'_{12_e} * h'_{21_e}$$
$$\Delta h_e' = h'_{11_e} * h'_{22_e} - h'_{12_e} * h'_{21_e}$$
$$\Delta h_e' \approx \left(h_{11_e} + h_{21_e} * R_E\right) * h_{22_e} - \left(h_{12_e} + h_{22_e} * R_E\right) * h_{21_e}$$
$$\Delta h_e' \approx h_{11_e} * h_{22_e} + h_{21_e} * h_{22_e} * R_E - h_{12_e} * h_{21_e} + h_{22_e} * R_E * h_{21_e}$$
$$\Delta h_e' \approx \Delta h_e$$

Berechnung der Betriebsgrößen
Eingangswiderstand

$$\underline{Z}'_{ein_{Tr}} = \frac{h'_{11_e} + \Delta h'_e * R_L}{1 + h'_{22_e} * R_L}$$

$$\underline{Z}'_{ein_{Tr}} = \frac{h_{11_e} + h_{21_e} * R_E + \Delta h_e * R_L}{1 + h_{22_e} * R_L}$$

$$\underline{Z}'_{ein_{Tr}} \approx h_{11_e} + h_{21_e} * R_E$$
$$\underline{Z}'_{ein_{St}} = R_B \,//\, \underline{Z}'_{ein_{Tr}}$$

Ausgangswiderstand

$$\underline{Z}'_{aus_{Tr}} = \frac{h'_{11_e} + R_G}{\Delta h'_e + h'_{22_e} * R_G}$$

$$\underline{Z}'_{aus_{Tr}} \approx \frac{h_{11_e} + h_{21_e} * R_E + R_G}{\Delta h'_e + h_{22_e} * R_G}$$

Mit $\Delta h_e \approx h_{11_e} * h_{22_e}$

$$\underline{Z}'_{aus_{Tr}} \approx \frac{h_{11_e} + h_{21_e} * R_E + R_G}{h_{22_e}\left(h_{11_e} + R_G\right)}$$

$$\underline{Z}'_{aus_{Tr}} \approx \frac{\left(h_{11_e} + R_G\right)}{h_{22_e}\left(h_{11_e} + R_G\right)} + \frac{h_{21_e} * R_E}{h_{22_e}\left(h_{11_e} + R_G\right)} \quad \Rightarrow \quad \underline{Z}'_{aus_{Tr}} \approx \frac{1}{h_{22_e}} + \frac{h_{21_e} * R_E}{h_{22_e}\left(h_{11_e} + R_G\right)}$$

$$\underline{Z}'_{aus_{Tr}} \approx \underline{Z}_{aus_{Tr}} + \frac{h_{21_e} * R_E}{h_{22_e}\left(h_{11_e} + R_G\right)}$$
$$\underline{Z}'_{aus_{St}} = \underline{Z}'_{aus_{Tr}} \,//\, R_C$$

Stromgegenkopplung-Betriebsgrößen:

Spannungsverstärkung

$$\underline{V}'_u = -\frac{h'_{21_e} * R_L}{h'_{11_e} + \Delta h'_e * R_L}$$

$$\underline{V}'_u \approx -\frac{h_{21_e} * R_L}{h_{11_e} + h_{21_e} * R_E + \Delta h_e * R_L}$$

$$\underline{V}'_u = \frac{\underline{V}_u}{1 - \underline{K}_u * \underline{V}_u} \quad \text{mit} \quad \underline{K}_u = \frac{R_E}{R_L}$$

$$\underline{V}'_u \approx \frac{\underline{V}_u}{1 + \frac{R_E}{R_L} * \underline{V}_u}$$

Bei hoher Verstärkung:

$$\left|\underline{K}_u * \underline{V}_u\right| >> 1$$

$$\Rightarrow \quad \underline{V}'_u \approx \frac{\underline{V}_u}{\underline{K}_u * \underline{V}_u}$$

$$\underline{V}_u \approx \frac{R_L}{R_E}$$

Sromverstärkung

$$\underline{V}'_{i_{Tr}} = \frac{h'_{21_e}}{1 + h'_{22_e} * R_L} \quad \Rightarrow \quad \underline{V}'_{i_{Tr}} \approx \frac{h_{21_e}}{1 + h_{22_e} * R_L}$$

$$\underline{V}'_{i_{Tr}} \approx \underline{V}_{i_{Tr}}$$

$$\underline{V}_{i_{St}} = \frac{R_B}{R_B + \underline{Z}_{ein_{Tr}}} * \underline{V}_{i_{Tr}} * \frac{R_C}{R_C + R_A} \quad \Rightarrow \quad \underline{V}'_{i_{St}} = \frac{R_B}{R_B + \underline{Z}'_{ein_{Tr}}} * \underline{V}_{i_{Tr}} * \frac{R_C}{R_C + R_A}$$

Es gilt mit $\underline{Z}'_{ein_{Tr}} > \underline{Z}_{ein_{Tr}}$

$$\underline{V}'_{i_{St}} \neq \underline{V}_{i_{St}}$$

Y' - Parameter

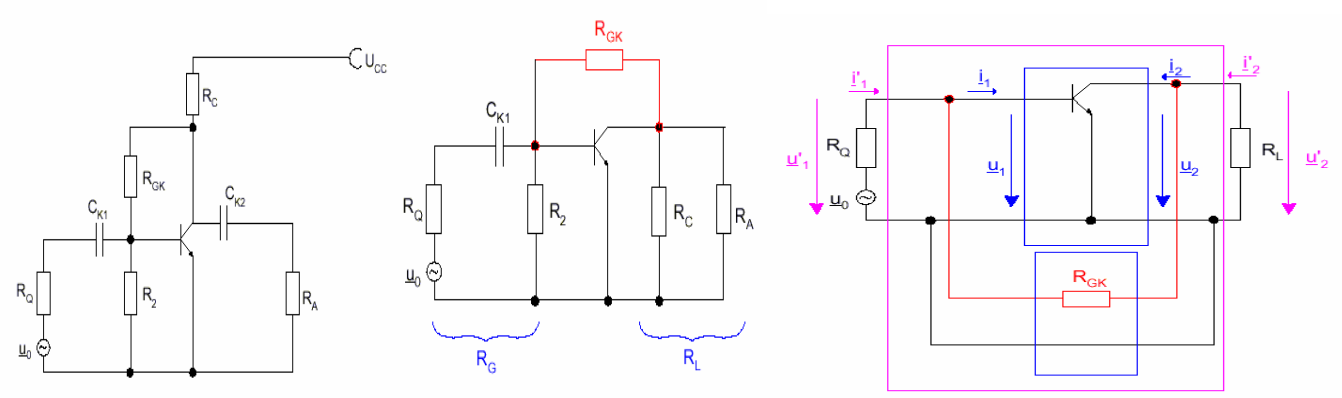
$$Y'_{11_e} = \frac{Y_{11_e} + \Delta Y_e * R_e}{1 + \Sigma Y_e * R_e} \approx \frac{Y_{11_e}}{1 + Y_{21_e} * R_E} \quad \Rightarrow \quad Y'_{12_e} = \frac{Y_{12_e} - \Delta Y_e * R_e}{1 + \Sigma Y_e * R_e} \approx \frac{Y_{12_e}}{1 + Y_{21_e} * R_E}$$

$$Y'_{21_e} = \frac{Y_{21_e} - \Delta Y_e * R_e}{1 + \Sigma Y_e * R_e} \approx \frac{Y_{21_e}}{1 + Y_{21_e} * R_E} \quad \Rightarrow \quad Y'_{22_e} = \frac{Y_{22_e} - \Delta Y_e * R_e}{1 + \Sigma Y_e * R_e} \approx \frac{Y_{22_e}}{1 + Y_{21_e} * R_E}$$

$$\Delta Y'_e = \frac{\Delta Y_e}{1 + \Sigma Y_e * R_e} \approx 0$$

Ein ausführliches Rechenbeispiel ist auf der Seite 79 im Skript

Spannungsgegenkopplung(Widerstand Basis-Kollektor):



Spannungs - Gegenkopplung

$$\underline{u}'_1 = \underline{u}_1$$
$$\underline{u}'_2 = \underline{u}_2$$
$$\underline{i}'_1 = \underline{i}_1 - \underline{i}_{GK}$$
$$\underline{i}'_2 = \underline{i}_2 + \underline{i}_{GK}$$

$$\Delta h' = \frac{\Delta h + \frac{h_{11}}{R_{GK}}}{1 + \frac{h_{11}}{R_{GK}}}$$

$$h'_{12} = \frac{h_{12} + \frac{h_{11}}{R_{GK}}}{1 + \frac{h_{11}}{R_{GK}}}$$

$$h'_{21} = \frac{h_{21} - \frac{h_{11}}{R_{GK}}}{1 + \frac{h_{11}}{R_{GK}}}$$

$$h'_{11} = \frac{h_{11}}{1 + \frac{h_{11}}{R_{GK}}}$$

$$h'_{22} = h_{22} + \frac{(1 + h_{21})(1 - h_{12})}{h_{11} + R_{GK}}$$

Näherungen für die Emitterschaltung

$$\frac{h_{11_e}}{R_{GK}} << 1$$

$$h_{12_e} << 1$$

$$h_{21_e} >> 1$$

$$h'_{11_e} \approx h_{11_e}$$
$$h'_{12_e} \approx h_{12_e} + \frac{h_{11_e}}{R_{GK}}$$
$$h'_{21_e} \approx h_{21_e}$$
$$h'_{22_e} \approx h_{22_e} + \frac{h_{21_e}}{R_{GK}}$$
$$\Delta h'_e \approx \Delta h_e \approx h_{11_e} * h_{21_e}$$

Berechnung der Betriebsgrößen

Eingangswiderstand

$$\underline{Z}'_{ein_{Tr}} = \frac{h_{11_e} + \Delta h_e * R_L}{1 + h_{22_e} * R_L + \frac{h_{21_e}}{R_{GK}} * R_L} = \frac{h_{11_e}}{1 + h_{21_e} * \frac{R_L}{R_{GK}}}$$

$$\underline{Z}'_{ein_{Tr}} < \underline{Z}_{ein_{Tr}}$$

$$\underline{Z}_{ein_{St}} = R_B \,//\, \underline{Z}'_{ein_{Tr}} \quad (\underline{Z}'_{ein_{St}} = R_2 \,//\, \underline{Z}'_{ein_{Tr}})$$

Ausgangswiderstand

$$\underline{Z}'_{aus_{Tr}} = \frac{h'_{11_e} + R_G}{\Delta h'_e + h'_{22_e} * R_G}$$

$$\underline{Z}'_{aus_{Tr}} \approx \frac{h_{11_e} + R_G}{h_{21_e} * \frac{R_G}{R_{GK}}}$$

$$\underline{Z}'_{aus_{Tr}} < \underline{Z}_{aus_{Tr}}$$
$$\underline{Z}'_{aus_{St}} = \underline{Z}'_{aus_{Tr}} \,//\, R_C$$

Stromverstärkung

$$\underline{V}'_{i_{Tr}} = \frac{h'_{21_e}}{1 + h'_{22_e} * R_L} \quad \Rightarrow \quad \underline{V}'_{i_{Tr}} \approx \frac{h_{21_e}}{1 + \left(h_{22_e} + \frac{h_{21_e}}{R_{GK}}\right) * R_L} = \frac{h_{21_e}}{1 + h_{22_e} * R_L + \frac{R_L}{R_{GK}} * h_{21_e}}$$

$$\underline{V}'_{i_{Tr}} = \frac{\underline{V}_{i_{Tr}}}{1 - \underline{K}_i * \underline{V}_{i_{Tr}}} \quad \text{mit} \quad \underline{K}_i = -\frac{R_L}{R_{GK}}$$

$$\underline{V}'_{i_{Tr}} \approx \frac{h_{21_e}}{1 + h_{21_e} * \frac{R_L}{R_{GK}}}$$

Mit $\left|\underline{K}_i * \underline{V}_{i_{Tr}}\right| >> 1 \quad \Rightarrow \quad \underline{V}_{i_{Te}} \approx \frac{R_{GK}}{R_L}$

$$\underline{V}'_{i_{St}} = \frac{R_B}{R_B + \underline{Z}'_{ein_{Tr}}} * \underline{V}'_{i_{Tr}} * \frac{R_C}{R_C + R_A}$$

Spannungsverstärkung

$$\underline{V}'_u = -\frac{h'_{21_e} * R_L}{h'_{11_e} + \Delta h'_e * R_L} \quad \Rightarrow \quad \underline{V}'_u \approx -\frac{h_{21_e} * R_L}{h_{11_e} + \Delta h_e * R_L}$$

$\underline{V}'_u = \underline{V}_u$, denn $\underline{V}_u = \frac{\underline{u}_2}{\underline{u}_1}$ und $\underline{V}'_u = \frac{\underline{u}'_2}{\underline{u}'_1}$

Y' - Parameter

$$Y'_{11} = Y_{11} + \frac{1}{R_{GK}}$$
$$Y'_{12} = Y_{12} - \frac{1}{R_{GK}}$$
$$Y'_{21} = Y_{21} - \frac{1}{R_{GK}}$$
$$Y'_{22} = Y_{22} - \frac{1}{R_{GK}}$$
$$\Delta Y' = \Delta Y + \frac{\sum Y}{R_{GK}}$$

Beispiele ab der Seite 85 im Skript

Frequenzabhängigkeit der Verstärkung :

Grenzfrequenz :

$\omega = \omega_g$, wenn $|\underline{V}| = \frac{|\underline{V}_m|}{\sqrt{2}} = 0{,}707 * |\underline{V}_m|$

$$\omega_{g_o} = \frac{1}{C_{P_1}\left(R_Q \,//\, R_B \,//\, \underline{Z}_{ein_{Tr}}\right)}$$

$$\omega_{g_u} = \frac{1}{C_K\left(R_V + R_W\right)}$$
$$C_K = \frac{1}{\omega_{g_u}\left(R_V + R_W\right)}$$

Koppelkondensator am Eingang der Stufe

$$C_{K_1} = \frac{1}{2\pi * f_{g_u} * \left(R_Q + \underline{Z}_{ein_{St}}\right)}$$

(für -3dB) (bei einer Gegenkopplung $\underline{Z}'_{ein_{St}}$)

Koppelkondensator am Ausgang der Stufe

$$C_{K_2} = \frac{1}{2\pi * f_{g_u} * \left(\underline{Z}_{aus_{St}} + R_A\right)}$$

Kopplung zweier Verstärkerstufen

$$C_{K_2} = \frac{1}{2\pi * f_{g_u} * \left(\underline{Z}_{aus_{St}} + \underline{Z}_{ein_{St}}\right)}$$

$$C_E = \frac{1}{\omega_{g_u} * R_E} \sqrt{\left(\frac{\underline{V}^*_u}{\underline{V}_{u_{\min}}}\right)^2 - 2}$$

$$\underline{V}_{u_{\max}} = -\frac{h_{21_e} * R_L}{h_{11_e}} \quad ; \quad \underline{V}_{u_{\min}} = -\frac{h_{21_e} * R_L}{h_{11_e} + h_{21_e} * R_L} \quad ; \quad \frac{\underline{V}_{u_{\max}}}{\underline{V}_{u_{\min}}} = \frac{h_{11_e} + h_{21_e} * R_L}{h_{11_e}}$$

Zwei Möglichkeiten
für den Korrekturfaktor

1. $k = \frac{1}{\sqrt{\sqrt[n]{2} - 1}}$ mit $P_k * n = -3dB$

2. $k = \frac{a_k}{\sqrt{1 - a_k^2}}$ mit $a_k = \frac{P_k}{1020} < 1$

$-P_k$ / dB	n	k	a_k	k
3	1	1	0,7079	1
2,5	1,2	1,13	0,7499	1,13
2	1,5	1,30	0,7943	1,31
1,5	2	1,56	0,8419	1,56
1	3	1,96	0,8913	1,97
0,5	6	2,86	0,9441	2,86
0,3	10	3,73	0,9661	3,74
0,1	30	6,54	0,9886	6,57

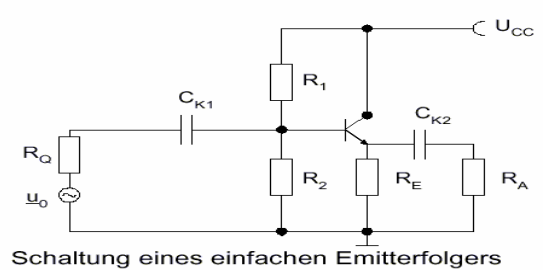
$$C_{K_1} = k * C_{K_{1(bei-3dB)}} \quad ; \quad C_{K_2} = k * C_{K_{2(bei-3dB)}} \quad ; \quad C_E = k * C_{E_{(bei-3dB)}}$$

Beispiel auf der Seite 94 im Skript .

Kollektorschaltung (Emitterfolger)

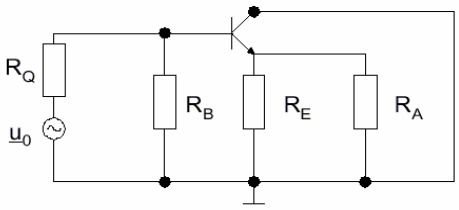
- hoher Eingangswiderstand
- niedriger Ausgangswiderstand
- Spannungsverstärkung ≈ 1
- gleiche Phasenlage zwischen Ein- und Ausgangsspannung

Anwendung : Impedanzwandler



Schaltung eines einfachen Emitterfolgers

Wechselstrom - Ersatzschaltbild :



Eingang : Basis - Kollektor
Ausgang : Emitter - Kollektor

Betriebsgrößen

Eingangswiderstand

$$\underline{Z}_{ein_{CTr}} = \frac{h_{11_c} + \Delta h_c * R_L}{1 + h_{22_c} * R_L}$$

$$\underline{Z}_{ein_{CTr}} \approx h_{11_e} + h_{21_e} * R_L$$

$$\underline{Z}_{ein_{CSt}} = R_L \,//\, \underline{Z}_{ein_{CTr}}$$

Ausgangswiderstand

$$\underline{Z}_{aus_{CTr}} = \frac{h_{11_c} + R_G}{\Delta h_c + h_{22_c} * R_G}$$

$$\underline{Z}_{aus_{CTr}} \approx \frac{h_{11_c} + R_G}{h_{21_c}}$$

$$\underline{Z}_{aus_{CSt}} = \underline{Z}_{aus_{CSt}} \,//\, R_E$$

Umrechnung der h - Parameter

$$h_{11_c} \approx h_{11_e} \quad ; \quad h_{12_c} \approx 1 - h_{12_e} \approx 1$$

$$h_{21_c} \approx -\left(1 + h_{21_e}\right) \quad ; \quad h_{22_c} \approx h_{22_e}$$

$$\Delta h_c \approx \left(1 + h_{21_e}\right)$$

Spannungsverstärkung

$$\underline{V}_{u_C} = -\frac{h_{21_c} * R_L}{h_{11_c} + \Delta h_c * R_L} \quad \Rightarrow \quad \underline{V}_{u_C} = -\frac{-\left(1 + h_{21_e}\right) * R_L}{h_{11_c} + \left(1 + h_{21_e}\right) * R_L}$$

$$\underline{V}_{u_C} = \frac{1}{\frac{h_{11_c}}{\left(1 + h_{21_e}\right) * R_L} + 1} \approx 1 \qquad \text{mit } h_{11_e} << \left(1 + h_{21_e}\right) * R_L$$

Stromverstärkung

$$\underline{V}_{i_{CTR}} = \frac{h_{21_c}}{1 + h_{22_c} * R_L} \quad \Rightarrow \quad \underline{V}_{i_{CTR}} \approx \frac{\left(1 + h_{21_e}\right)}{1 + h_{22_e} * R_L}$$

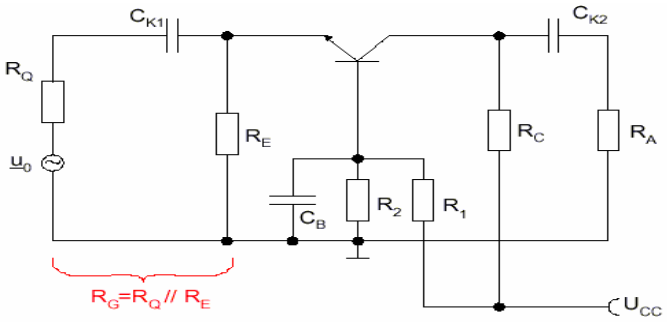
$$\underline{V}_{i_{CTR}} \approx -h_{21_e} \quad \Rightarrow \quad \text{Phasendrehung}$$

$$\underline{V}_{i_{CSt}} \approx -\frac{R_B}{R_B + \underline{Z}_{ein_{CTR}}} * h_{21_c} * \frac{R_E}{R_E + R_A}$$

Beispiel Seite 97 im Skript.

Basisschaltung

- kleiner Eingangswiderstand
- hoher Ausgangswiderstand
- Stromverstärkung ≈ 1



Umrechnung der h - Parameter

$$h_{11_b} = \frac{h_{11_e}}{1+h_{21_e}} \quad ; \quad h_{12_b} = \frac{\Delta h_e - h_{12_e}}{1+h_{21_e}}$$

$$h_{22_b} = -\frac{h_{21_e}}{1+h_{21_e}} \quad ; \quad h_{22_b} = \frac{h_{22_e}}{1+h_{21_e}}$$

$$\Delta h_b = \frac{\Delta h_e}{1+h_{21_e}}$$

Die Basisschaltung dient zur Anpassung niederohmiger Quellen an hochohmige Schaltungen.

$$\underline{Z}_{ein_{bTr}} = \frac{h_{11_b} + \Delta h_b * R_L}{1 + h_{22_b} * R_L} \quad \Rightarrow \quad \underline{Z}_{ein_{bTr}} \approx \frac{\frac{h_{11_b}}{1+h_{21_b}} + \frac{\Delta h_b * R_L}{1+h_{21_b}}}{\frac{1+h_{21_b}}{1+h_{21_b}} + \frac{h_{22_b} * R_L}{1+h_{21_b}}} = \frac{h_{11_b} + \Delta h_b * R_L}{1 + h_{21_b} + h_{22_b} * R_L}$$

$$\boxed{\underline{Z}_{ein_{bTr}} \approx \frac{h_{11_b}}{h_{22_b}}} \qquad \boxed{\underline{Z}_{ein_{bSt}} = R_E \,//\, \underline{Z}_{ein_{bTr}}}$$

$$\underline{Z}_{aus_{bTr}} = \frac{h_{11_b} + R_G}{\Delta h_b + h_{22_b} * R_G}$$

$$\boxed{\underline{Z}_{aus_{Tr}} \approx \frac{1}{h_{22_e}}}$$

$$\underline{Z}_{aus_{bTr}} \approx \frac{h_{11_e} + R_G * \left(1 + h_{21_e}\right)}{\Delta h_e + h_{22_e} * R_G} = \frac{h_{11_e} + R_G}{\Delta h_e + h_{22_e} * R_G} + \frac{h_{21_e} * R_G}{\Delta h_e + h_{22_e} * R_G}$$

$$\boxed{\underline{Z}_{aus_{bTr}} \approx \frac{1}{\Delta h_e + h_{22_e} * R_G} + \frac{h_{21_e} * R_G}{\Delta h_e + h_{22_e} * R_G}} \qquad \boxed{\underline{Z}_{aus_{bSt}} = \underline{Z}_{ein_{bTr}} \,//\, R_C \approx R_C}$$

$$\underline{V}_u = -\frac{h_{21_b} * R_L}{h_{11_b} + \Delta h_b * R_L} \quad \Rightarrow \quad \underline{V}_{u_b} = -\frac{-h_{21_e} * R_L}{h_{11_e} + \Delta h_e * R_L} - \underline{V}_{u_e}$$

$$\underline{V}_{i_{bTr}} = \frac{h_{21_b}}{1 + h_{22_b} * R_L} = \frac{-h_{21_e}}{\left(1 + h_{21_e}\right) + h_{22_e} * R_L}$$

$$\boxed{\underline{V}_{i_{bTr}} \approx -1} \qquad \boxed{\underline{V}_{i_{bSt}} = \frac{R_E}{R_E + \underline{Z}_{ein_{bTr}}} * (-1) * \frac{R_C}{R_C + R_A}}$$